

CLAIMS

What is claimed is:

1. A method for fabricating a feature into a semiconductor substrate, the method comprising:
 - (a) encapsulating with an etch-resistant material around an opening and
5 sidewalls of a mask defining a feature nominally etched into the semiconductor substrate;
 - (b) depositing an amorphous carbon liner on the sidewalls of the mask and sidewalls of the etched feature;
 - (c) performing an amorphous carbon liner etch for removing excess
10 amorphous carbon that may have deposited around the opening or the sidewalls of the mask during the deposition of the amorphous carbon liner,
wherein the etch-resistant material preventing or mitigating etching of the around the opening and the sidewalls of the mask during the amorphous carbon liner etch; and
 - 15 (d) performing a feature etch to deepen the depth of the feature into the semiconductor substrate.
2. The method of claim 1, further comprising repeating (d) one or more times until the feature has been etched to a desired depth into the semiconductor substrate.
3. The method of claim 1, further comprising repeating (b) and (d) each one or
20 more times until the feature has been etched to a desired depth into the semiconductor substrate.
4. The method of claim 1, further comprising repeating (b) and (c) one or more iterations to replenish the amorphous carbon liner.
5. The method of claim 1, further comprising periodically repeating (a) to
25 replenish the etch-resistant material around the opening and the sidewalls of the mask.
6. The method of claim 1, further comprising performing (b) and (c) one or more cycles to achieve a desired profile of the opening and the sidewalls of the mask.
7. The method of claim 1, further comprising performing (b) and (c) one or more cycles to achieve a desired profile of the amorphous carbon liner.
- 30 8. The method of claim 7, wherein the desired profile is characterized by:
 - (i) a desired uniformity of thickness of the amorphous carbon liner,

- (ii) a desired depth of the amorphous carbon liner within the feature; or
 - (iii) both (i) and (ii).
- 9. The method of claim 1, wherein the amorphous carbon liner is resistant to lateral etching of the feature during the feature etch.
- 5 10. The method of claim 1, wherein the amorphous carbon liner enables a tighter critical dimension control (CD) of the feature during the feature etch relative to performing the feature etch without the amorphous carbon liner.
- 11. The method of claim 1, wherein the encapsulation with the etch-resistant material enables one or more of the following:
 - 10 (i) the amorphous carbon liner etch to occur for a longer period of time before degrading the mask relative to if the mask had not been encapsulated;
 - (ii) the amorphous carbon liner to be deposited deeper into the feature and more uniformly on the sidewalls of the feature because excess amorphous carbon deposits is removed around the opening and the sidewalls of the mask during the
 - 15 amorphous carbon liner etch; or
 - (iii) the feature etch is performed deeper because the amorphous carbon liner needs to be replenished less often because it extends deeper and more uniformly on the sidewalls of the feature.
- 12. The method of claim 1, wherein the mask is one of the following:
 - 20 (i) an Ashable HardMask (AHM);
 - (ii) a carbon mask; or
 - (iii) a doped material.
- 13. The method of claim 12, wherein the doped material is either Boron or Tungsten.
- 25 14. The method of claim 1, wherein the etch-resistant material is etch-resistant to chemistries used to etch amorphous carbon.
- 15. The method of claim 1, wherein the etch-resistant material is one of the following:
 - (i) silicon nitride;
 - 30 (ii) silicon oxide; or
 - (iii) a combination of (i) and (ii).

16. The method of claim 1, wherein the feature is one of the following: a cylinder, a hole, a trench, a slit, a geometric shape or a non-geometric shape.
17. The method of claim 1, prior to (a), further comprising:
providing a mask material onto the semiconductor substrate;
5 patterning the mask to define the feature; and
performing a nominal etch, using the mask, the nominal etch defining the feature in the substrate prior to encapsulation of the mask.
18. A substrate processing tool, comprising:
a processing chamber;
10 a substrate holder for holding a substrate for processing in the processing chamber; and
a controller arranged to execute instructions for controlling processing steps within the processing chamber for processing the substrate, the controller arranged to:
(a) encapsulate with an etch-resistant material around an opening and
15 sidewalls of a mask defining a feature nominally etched into the semiconductor substrate;
(b) deposit an amorphous carbon liner on the sidewalls of the mask and sidewalls of the etched feature;
(c) perform an amorphous carbon liner etch for removing excess
20 amorphous carbon that may have deposited around the opening or the sidewalls of the mask during the deposition of the amorphous carbon liner.
19. The substrate processing tool of claim 18, wherein the controller is further configured to repeat (b) and (c) one or more iterations to replenish the amorphous carbon liner.
20. The substrate processing tool of claim 18, wherein the controller is further configured to repeat (a) to replenish the etch-resistant material around the opening and the sidewalls of the mask.
21. The substrate processing tool of claim 18, wherein the controller is further configured to repeat (b) and (c) one or more cycles to achieve a desired profile of the
30 opening and the sidewalls of the mask.

22. The substrate processing tool of claim 18, wherein the controller is further configured to perform (b) and (c) one or more cycles to achieve a desired profile of the amorphous carbon liner.
23. The substrate processing tool of claim 22, wherein the desired profile is
5 characterized by:
- (i) a desired uniformity of thickness of the amorphous carbon liner,
 - (ii) a desired depth of the amorphous carbon liner within the feature; or
 - (iii) both (i) and (ii).
24. The substrate processing tool of claim 18, wherein the etch-resistant material
10 is etch-resistant to chemistries used to etch amorphous carbon.
25. The substrate processing tool of claim 18, wherein the etch-resistant material is one of the following:
- (i) silicon nitride;
 - (ii) silicon oxide; or
 - 15 (iii) a combination of (i) and (ii).
26. The substrate processing tool of claim 18, wherein the controller is further configured to perform the nominal etch of the feature and one or more feature etch cycles to deepen the feature to a desired depth.

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